The following article is one chapter of the book

Björn Risch (Ed.)

Teaching Chemistry around the World

Waxmann 2010
Münster / New York / München / Berlin

Bibliographic information published by die Deutsche Nationalbibliothek
Die Deutsche Nationalbibliothek lists this publication in the
Deutsche Nationalbibliografie; detailed bibliographic data
is available in the Internet at http://dnb.d-nb.de.

ISBN 978-3-8309-2296-4

Postfach 8603, 48046 Münster

www.waxmann.com
info@waxmann.com

Cover Design: Christian Averbeck, Münster
Cover Picture: Björn Risch, Bielefeld
Print: Hubert & Co., Göttingen
Printed on age-resistant paper, acid-free as per ISO 9706

Printed in Germany

Vanessa Kind[1]

United Kingdom

Basic Structure of the Educational System

Education is compulsory for five- to sixteen-year-olds in all four nations comprising the UK, namely, England, Northern Ireland, Scotland and Wales: children must start formal education in the school year in which their fifth birthday falls between 1st September and 31st August. Thus, the basic entitlement to education paid for by the state lasts eleven years. However, optional state-funded education is also offered to three- to five-year-olds: during the school year, three-year-olds are entitled to 12.5 hours per week in a nursery, while four-year-olds can attend full-time, formal “Reception” classes linked to schools for five- to seven- or five- to eleven-year-olds. Reception classes are popular and are viewed positively by many families. Older pupils, although they can leave school at the age of sixteen, are now expected to remain in further education or training to age eighteen. An extra year beyond the age of eighteen is available for pupils needing to re-take a year due to illness or other personal factors. Hence, a pupil could receive education from age three to nineteen.

The UK school year begins in September and ends in July. School years are divided into three periods, called “terms”, of roughly three months. Each term is further divided into two halves by a one week “half-term” break. Local traditions dictate precise timings of school holidays across the country. A typical school day begins between 8.30 and 9.00 am and ends between 3.00 and 3.30 pm for all children regardless of age, although a few schools have adopted a “continental” day beginning at around 8.00 am and ending at 2.00 pm. Secondary school lessons last typically one hour each, but this varies considerably – school managers are free to decide how best to organise timetables for their pupils and staff. Provision of school meals is a strong UK tradition: children of all ages have access to a hot lunchtime meal, often cooked on their school’s premises. Children from low income families are entitled to free school meals – the proportion of children receiving free school meals is regarded as a measure of the extent of poverty in a local community. Those who do not want a school meal can bring food to school as a “packed lunch”. Some schools open earlier, so pupils can arrive in time to have breakfast, as this is also regarded as important for ensuring children are well-fed and ready for their education.

1 Note that any opinions expressed are those of the author and are made in a personal capacity.

State education is funded by a combination of local and national taxation. Local Authorities (LAs) in each region control the type of school and pupil numbers, and with school management teams are responsible for appointing and supporting teachers. National organisations such as the Qualifications and Curriculum Development Authority (QCDA from July 2009, formerly QCA) and the Office for Standards in Education (Ofsted) determine curriculum and assessment and inspection regimes respectively. Children in the UK attend primary school from age five to eleven and secondary school from age eleven to sixteen or eleven to nineteen. Primary education is split between "infant" for five- to seven-year-olds and "junior" for seven- to eleven-year-olds. Within this, variation between nations and local areas is apparent. For example, in Scotland, pupils start university education aged seventeen; in some areas of England children transfer to secondary school at age thirteen, rather than eleven. Secondary schools nationwide can be for eleven- to sixteen-year-olds, with separate schools for sixteen- to nineteen-year-olds, but some LAs provide eleven to nineteen secondary schools or a mixture of eleven to sixteen, eleven to nineteen and sixteen to nineteen schools. Secondary schools for girls or boys only and those with a religious outlook are also found, although the distribution of such schools is inconsistent across the nation. A few LAs offer "selective" secondary education, in which access to academically-oriented "grammar" schools is determined by competitive examination taken at age eleven. Most areas offer comprehensive, that is, non-selective education for all children at all phases.

Chemistry becomes a recognisable subject at secondary school, and is taught at many universities throughout the UK.

Differences Between England, Wales, Northern Ireland and Scotland

In Northern Ireland, England and Wales, compulsory education divides into Key Stages (KS) numbered 1–4: KS1 refers to five- to seven-year-olds; KS2 to eight- to eleven-year-olds; KS3 to eleven- to fourteen-year-olds and KS4 to fourteen- to sixteen-year-olds. Overlap in ages between KS2, 3 and 4 occurs as teachers are able to decide exactly when to start teaching the curriculum content. The four Key Stages are underpinned by the Foundation Stage for three- to five-year-olds. Science is a "core" curriculum subject, meaning that children are assessed in their progress from KS1 onwards. KS1 assessments are carried out by teachers. At KS2 children are assessed by their teachers and, up to 2009, through formal, national examinations, called Standard Assessment Tests (SATs). Achievement at KS3 and 4 has been measured by SATs and General Certificate of Secondary Education (GCSE) examinations respectively. Recent changes mean that from 2010 teacher assessments will be used to assess progress at KS2 and 3, while examinations remain for KS4. The National Curriculum defines what is taught: England and Wales have a joint document [1], while Northern Ireland has a separate document [2].

The education system in Scotland runs differently to the rest of the UK. Here, there is no national curriculum – local school areas are responsible for deciding what to teach. At age fourteen, children enter “Standard Grade” 3, and prepare for “Standard Grade” examination programmes, but can take Intermediate and Higher Level Qualifications to prepare for university entrance [3].

The main focus for this paper will be the National Curriculum for England and Wales, as this is learned by and influences the chemical education of the majority of the population of the UK. Nevertheless, the Scottish and Northern Irish systems make positive, distinctive contributions to science teaching and learning in the UK. For example, the Northern Ireland curriculum adopts a social emphasis on development of individuals and the contributions that pupils can make to society, while the independence of the Scottish system is regarded as leading to high standards of professionalism among teachers and good levels of knowledge among its pupils.

The Origins of Science in UK Schools

Science in England and Wales originated as a school subject in the 1850s, as the Industrial Revolution and significant discoveries, theories and inventions began to impact on daily life. School science began as part of a “gentleman’s education”, being offered at various public (fee-paying) schools. In 1902, Local Education Authorities (now called Local Authorities) responsible for primary and secondary schools in their own areas were established. Science took its place as a subject, based mainly on rote learning. The horrors of the First World War brought changes, as realisation dawned that better levels of scientific knowledge may have helped reduce the trauma soldiers suffered. In response, knowledge-based science courses were developed, split by gender and ability, so boys learned physics, chemistry, car maintenance and “rural science”, that is, growing food and caring for the land, while girls learned biology, botany, zoology and “domestic science”, that is, cookery and housekeeping skills.

The post-Sputnik era of the 1950s–1960s saw some science curricula develop along heuristic lines, adopting principles established by the Nuffield Foundation (Waring, 1979) – that children should work “as scientists” discovering for themselves. This contributed to practical science, experimentation and investigation becoming popular in school science lessons, traditions which retain a strong focus in the British system today. 1950s–1970s school science focused heavily on preparing high ability pupils for university entrance using a combination of factual learning and development of specific practical and technical skills. In the 1960s and 1970s, a system of comprehensive schools was implemented in England and Wales that ensured all children were taught together, rather than in separate schools on the basis of spurious intelligence test results. Science courses allowed some variation at age sixteen – high ability pupils were taught to “Ordinary”, or “O” level standard, while others followed “Certificate of Secondary Education”, or “CSE” courses. In 1988 these were combined into one qualification, the General Certificate of Secondary Education (“GCSE”). Gender differences, specifically girls favouring biology and boys physics, remained.

In 1989, a new, formal National Curriculum was implemented that described for the first time the entitlement for all children aged five to sixteen. Science was taught under the principle “science for all”, meaning that all pupils should study all three sciences. Subsequently, discussion took place about whether the science described in the National Curriculum was suitable for everyone. An influential report “Beyond 2000” [4] suggested changes were necessary in order to better address the science learning needs of every pupil. Millar and Osborne proposed scientific literacy as the organising principle, while achieving a high level of detailed factual science knowledge is an option for specific pupils. They suggested adopting “explanatory stories”, such as the particulate nature of matter, and the Earth as a planet in a Universe, as key content for everyone, together with teaching “ideas-about-science”, that is, ideas showing how reliable knowledge about the natural world has been and is being obtained [4]. Following widespread discussion, the National Curriculum was revised for fourteen- to sixteen-year-olds in 2004 and for eleven- to fourteen-year-olds in 2007. The formal academic content was reduced drastically and scientific enquiry, or “How Science Works”, was introduced to embrace scientific literacy themes allied to practical skills. The content described here refers to these latest revisions.

Science in Key Stages

The England and Wales National Curriculum for science is divided into four sections entitled “scientific enquiry” (How Science Works); “life processes and living things”; “materials and their properties”; and “physical processes”. Chemistry features are mainly covered in the section “materials and their properties”. The themes are introduced through the Foundation stage (for three- to five-year-olds) and primary education, to ensure that secondary aged children are fully prepared for more detailed knowledge and conceptual understanding. A brief description of science education in each stage is provided.

Foundation stage education for under five-year-olds

The Foundation stage curriculum offers a wide range of skill- and play-based activities that help develop good learning and social skills. Children are encouraged to read, write and develop basic number skills. They learn to use computers, play sports, make observations about their world, take part in artistic and other projects and visit locations of interest in their area. Science is introduced through using the senses to collect information, for example about “hot” and “cold” environments or objects; seeing changes, such as in growth of plants; looking at differences between objects and making simple measurements.

Primary education for five- to eleven-year-olds

The primary curriculum is broad, providing legal entitlement to learn art and design, design and technology, English, geography, history, information and communication technology, mathematics, music, physical education, religious education and science. Access to one or more foreign language, usually French, German and/or Spanish, is also an entitlement. Primary school teachers have to allocate time carefully to ensure the curriculum is covered. The recent Rose Review [5] of the primary curriculum has explored this, recommending that "science and technological understanding" remains one of six major areas of learning.

Key Stage 1

At Key Stage 1, children are introduced to simple experiments to collect evidence by making observations and measurements, asking "How?", "Why?" and "What will happen if …?" questions. The section of the curriculum related to chemistry ensures that similarities and differences between materials are taught, together with properties that enable groupings to be made by texture, use, and/or density, as well as how materials change by squashing, bending or twisting, heating and cooling.

Key Stage 2

At Key Stage 2, children learn to plan an investigation, considering data they need to collect and how to make a test "fair" by changing one factor at a time. Simple equipment, such as data-loggers, is introduced to help systematic data collection. Children are taught to make repeat observations and to recognise rogue values. They examine data for patterns and draw conclusions that relate to predictions and scientific knowledge. Children's understanding of materials is developed by introducing properties such as magnetism, insulation/conductance of heat and electricity. Experiments relating to states of matter and reversible and non-reversible changes are carried out.

Secondary education for eleven- to sixteen-year-olds

Secondary education divides into two Key Stages – KS3 is for children aged between eleven and fourteen, while KS4 relates to pupils aged fourteen to sixteen. The recent reductions in academic content allow teachers more freedom to choose what they think is most appropriate to teach pupils in their schools. There is no formal requirement to select or use specific teaching materials, books or resources and teachers are free to organise their teaching as they wish. Usually teams of teachers work together to co-ordinate the science teaching for children in the school.

Key Stage 3

Rather than specify academic content, the curriculum [6] is now organised around the key concepts and principles shown in table 1, with the overall aim of enhancing scientific literacy. The content relating to chemistry states that children should learn:

– "the particle model provides explanations for the different physical properties and behaviour of matter
– elements consist of atoms that combine together in chemical reactions to form compounds
– elements and compounds show characteristic chemical properties and patterns in their behaviour" [7]

Table 1: Key Stage 3 Science National Curriculum: general organising themes and concepts [6]

Key concepts: How Science Works	**Key processes**	**Science learning opportunities**
• Use scientific ideas and models to explain phenomena and develop them creatively to generate and test theories • Critically analyse and evaluate evidence from observations and experiments • Explore how the creative application of scientific ideas can bring about technological developments and consequent changes in the way people think and behave • Examine the ethical and moral implications of using and applying science • Recognise that modern science has its roots in many different societies and cultures, and draws on a variety of valid approaches to scientific practice • Share developments	• use a range of scientific methods and techniques to develop and test ideas and explanations • assess risk and work safely in the laboratory, field and workplace • plan and carry out practical and investigative activities, both individually and in groups • obtain, record and analyse data from primary and secondary sources, including ICT sources, and use findings to provide evidence for scientific explanations • evaluate scientific evidence and working methods • use appropriate methods, including ICT, to communicate scientific information	• research, experiment, discuss and develop arguments • pursue an independent enquiry into an aspect of science of personal interest • use real-life examples as a basis for finding out about science • study science in local, national and global contexts, and appreciate the connections between these • experience science outside the school environment, including in the workplace, where possible • use creativity and innovation in science, and appreciate their importance in enterprise • recognise the importance of sustainability in scientific and technological developments • explore contemporary and historical scientific developments and how they have been communicated • prepare to specialise in a range of science subjects at key stage 4 and consider career opportunities both within science and in other areas that are provided by science qualifications • consider how knowledge and understanding of science informs

and common understanding across disciplines and boundaries	and contribute to presentations and discussions about scientific issues	personal and collective decisions, including those on substance abuse and sexual health • make links between science and other subjects and areas of the curriculum

Pupils will study science for approximately three hours each week. Common practice is to utilize a unit-based structure so pupils may experience the full range of sciences across the year. Some schools may divide science lessons formally into chemistry, physics and biology, but this relatively rare in state-funded secondary schools.

Key Stage 4: GCSE examination

GCSE courses are taught over two years to pupils aged fourteen to sixteen. Most pupils receive around five hours of science tuition each week. The most recent revision of the KS 4 Science National Curriculum took place in 2004. Table 2 lists the expected general content – compared to previous versions of the National Curriculum, these statements provide only brief requirements. Subject specific statements for chemistry are that pupils learn:

– chemical change takes place by the rearrangement of atoms in substances
– there are patterns in the chemical reactions between substances
– new materials are made from natural resources by chemical reactions
– the properties of a material determine its uses

Table 2: The content of scientific enquiry: How Science Works section of the Key Stage 4 National Curriculum in England and Wales, 2006 [6]

Scientific enquiry: How Science Works			
Data, evidence, theories and explanations	**Practical and enquiry skills**	**Communication skills**	**Applications and implications of science**
Pupils should be taught: • how scientific data can be collected and analysed • how interpretation of data, using creative thought, provides evidence to test ideas and develop theories • how explanations of many phenomena can	Pupils should be taught to: • plan to test a scientific idea, answer a scientific question, or solve a scientific problem • collect data from primary or secondary sources, including using ICT sources and tools	Pupils should be taught to: • recall, analyse, interpret, apply and question scientific information or ideas • use both qualitative and quantitative approaches • present information, develop an argument and	Pupils should be taught: • about the use of contemporary scientific and technological developments and their benefits, drawbacks and risks • to consider how and why decisions about science and technology are made, including those that raise

be developed using scientific theories, models and ideas • that there are some questions that science cannot currently answer, and some that science cannot address	• work accurately and safely, individually and with others, when collecting first-hand data • evaluate methods of collection of data and consider their validity and reliability as evidence	draw a conclusion, using scientific, technical and mathematical language, conventions and symbols and ICT tools	ethical issues, and about the social, economic and environmental effects of such decisions • how uncertainties in scientific knowledge and scientific ideas change over time and about the role of the scientific community in validating these changes

Assessment of pupils' learning at KS4 is by public examination, the GCSE. All pupils must take science as a GCSE subject. Although some will take only one GCSE in science ("GCSE Science"), many pupils study science for about 20% of their time in school, taking two GCSEs (Science and Additional Science) of which chemistry is a part. Some pupils, usually the most academic in any school, take three separate GCSEs in science, (a "Triple Award"), one each in Chemistry, Physics and Biology. Teachers choose the GCSE course they think is most appropriate for their pupils. Commonly, courses adopt a unit-based structure. Although all current GCSE science qualifications must include How Science Works and emphasise scientific literacy, the approach taken can vary. Tables 3 and 4 contrast a "traditional" with a context-based GCSE Chemistry course. These teach the same content, but adopt different strategies. The traditional course [7] (Table 3) comprises three units, presenting knowledge in a factual way, with scientific literacy and How Science Works mainly being added as additional information. A pupil needs to complete all three units successfully to gain the qualification.

Table 3: Content overview of a traditional-style GCSE Chemistry course [8]

Course	**Unit 1**			
	Patterns in Properties	**Making Changes**	**There's one Earth**	**Designer Products**
GCSE Science	Periodic Table – groups and periods Flame tests Colours and identification of transition metal compounds	Neutralisation reactions of dilute hydrochloric and sulphuric acids with oxides, carbonates and hydroxides Salt preparation	Global warming Hydrocarbons Fossil fuels Crude oil distillation Recycling materials	Modern materials – e.g. Lycra, Thinsulate Smart materials New materials

GCSE Chemistry	Properties of elements – e.g. chlorine, iodine, helium, iron, gold Rates of reaction Variations in reactivity Introduction to exothermic and endothermic reactions Using analytical data to identify elements/compounds	Metal extraction Oxidation reactions Order of reactivity of metals Hydration, dehydration, thermal decomposition Gas tests, gas preparation and collection Uses of common compounds	Sustainable development Biofuels Combustion Compounds and elements from sea water	Structure and properties related to use of materials
	Unit 2			
	Synthesis	**In Your Element**	**Chemical Structures**	**How Fast? How Furious?**
GCSE Science GCSE Chemistry	Cracking paraffin Structure of alkanes and alkenes Properties of alkanes and alkenes, bromine water to test for unsaturation Polymers – formation, types, properties, properties related to use Calculation of relative formula mass, theoretical and percentage yields Predicting outcomes of synthesis reactions	Physical properties and structures of metals Sub-atomic particles – charges and mass values Atomic structure Electronic configurations of the first 20 elements Ionic and covalent bonding Properties and structures of ionic and covalent compounds	The importance of chance in scientific discoveries, e.g. Buckminsterfullerene Uses of fullerenes and nanotubes Relationships between bonding, properties and structure of a range of substances, e.g. diamond, graphite, halogens	Exothermic and endothermic reactions Bond breaking is endothermic and bond making is exothermic The effects of changing temperature, concentration and surface area on a reaction rate The effects of a catalyst on a reaction rate Introduction to collision theory Haber process – concept of reversible chemical reactions

	Unit 3	
	Chemical Detection	**Chemistry Working for Us**
GCSE Chemistry	Identification of substances, purity testing Qualitative and quantitative analysis "Wet" tests for a range of ions Mole calculations Avogadro's Law Acid-base titrations Calculations of moles of gas	Properties and uses of transition metals Chemical and physical properties of alcohols, carboxylic acids and esters, and their uses Electrolysis Alkali metals, their compounds and uses Manufacture and uses of sulphuric acid Manufacture of soaps and detergents

The context-based course 21st Century Science (Table 4), offers an innovative approach, packaging the same content as the traditional course into seven units [9, 10]. The first three adopt a scientific literacy stance, setting out knowledge under the headings "issues for citizens" and "questions science could answer". The next three units pose questions for chemists, while the seventh unit completes the GCSE with more advanced material. Note that practical work is also expected – 10% of the traditional GCSE marks are awarded for practical skills assessed by the teacher, while 33.3% of the context-based course marks are awarded for a teacher-assessed practical investigation.

Teachers are free to choose the course they think is most appropriate for their school environment. Some teachers prefer traditional-style courses, perhaps because these offer greater familiarity with their own experiences as learners and/or are regarded as providing pupils with more in-depth chemical knowledge. Other teachers choose a context-based course because they think this makes chemistry more relevant to their pupils, thus enhancing motivation to study. Single subject chemistry GCSE was taken by about 77 000 pupils in England and Wales in 2008, compared to about 85 000 taking biology and 77 000 taking GCSE physics.

Table 4: Content overview of 21st Century Science GCSE Chemistry [11]

<table>
<tr><th>Course</th><th>Unit title</th><th colspan="2"></th></tr>
<tr><td colspan="2"></td><td>Issues for citizens</td><td>Questions science may help to answer</td></tr>
<tr><td rowspan="3">GCSE Science

GCSE Chemistry</td><td>Air Quality</td><td>How do I make sense of data about air pollution?
Where do pollutants come from?
Is air pollution harmful to me?
How can we improve air quality?</td><td>What chemicals make up air, and which ones are pollutants?
What chemical reactions produce air pollutants?
What happens to these pollutants in the atmosphere?
What choices can we make to improve air quality?</td></tr>
<tr><td>Material Choices</td><td>How can we pick a suitable material for a product or task?
When buying a product what else should we consider besides cost and how well it does its job?</td><td>What different properties do different materials have?
Why is crude oil important as a source of fibres and plastics?
Why does it help to know about the molecular structure of fibres and plastics?
How should we manage the wastes that arise from our use of materials?</td></tr>
<tr><td>Food matters</td><td>Is organic food better for us?
What are food additives and why are they used?
Are food additives safe to eat?
Why can it be harmful to eat too much sugary food?</td><td>What is the difference between intensive and organic farming?
Why are chemicals deliberately added to food?
How can we ensure our food does not contain chemicals that may harm our health?
Why does what we eat affect our health?</td></tr>
<tr><td colspan="2"></td><td colspan="2">Content overview</td></tr>
<tr><td rowspan="3">GCSE Additional Science

GCSE Chemistry</td><td>Chemical Patterns</td><td colspan="2">What are the patterns in the properties of the elements?
How do chemists explain the patterns in the properties of the elements?
How do chemists explain the patterns in the properties of compounds of group 1 and group 7 elements?</td></tr>
<tr><td>Chemicals of the natural environment</td><td colspan="2">What types of chemicals make up the atmosphere and hydrosphere?
What type of chemicals make up the Earth’s lithosphere?
Which chemicals make up the biosphere?
How can we extract useful materials from minerals?</td></tr>
<tr><td>Chemical synthesis</td><td colspan="2">Chemicals and why we need them
Planning, carrying out and controlling chemical synthesis</td></tr>
<tr><td>GCSE Chemistry</td><td>Further chemistry</td><td colspan="2">Alcohols, carboxylic acids and esters
Energy changes in chemistry
Reversible reactions and equilibria
Analysis
Green chemistry</td></tr>
</table>

Post-16 chemistry

Post-16 chemistry courses are of one or two years' duration. Pupils can take an Advanced Subsidiary General Certificate of Education (AS GCE) course in chemistry in one year as a complete qualification. A second year of study, known colloquially as "A2" (Advanced 2) can be added if they wish to pursue chemistry further. The AS and A2 years comprise the "Advanced GCE", known colloquially as "A level". Common practice among teachers is to expect pupils taking AS courses to have achieved a good standard in their Science or Chemistry GCSE examinations. Those progressing to A2 will normally have achieved or expect to achieve a pass standard in their AS course units. The knowledge and understanding required at A2 builds on that of AS, so pupils cannot take an A2 course without having first completed an AS course.

There is no formal post-16 National Curriculum dictating content, but all courses must meet the same minimum requirements and be validated by the QCDA. Traditional [12] and context-based courses are available. All courses require pupils to study three units, one of which involves assessment of practical skills. Courses also have to include How Science Works.

As at GCSE, teachers can choose which course best suits their pupils and expertise. Traditional courses are favoured by those who like to teach chemistry as a logical progression through chemical ideas in a fixed sequence. A context-based approach such as Salters Advanced Chemistry [13] is believed to offer greater relevance to pupils, promoting motivation. This method also permits pupils to re-visit chemical ideas as they are taught within certain contexts, rather than, for example, teaching all aspects of chemical bonding in one unit. Those preferring a context-based approach consider this enables pupils to build knowledge securely over a longer period than is possible in a traditional-style course.

In 2008, about 42 000 pupils completed A levels in chemistry. By comparison, around 56 000 pupils took A level biology and 28 000 A level physics. Generally, achieving a good grade in A level chemistry is regarded as very worthwhile and is a pre-requisite for studying a range of vocational sciences such as medicine, dentistry, veterinary science, pharmacy and dietetics.

Current Issues in School Chemistry

Ensuring the availability of science teachers with high quality specialist chemical knowledge in state schools is regarded as an important issue. Anecdotally, about 55% of graduates entering teacher education courses to teach science are biologists by background, while about 25% have chemistry or chemistry-related degrees, such as biochemistry. This has persisted for a number of years, creating an imbalance in expertise in secondary schools, such that some have only one or no teacher with the academic background thought to be necessary to teach A level chemistry. Thus, chemistry is regarded by the UK government as a "shortage" subject, that is, there are too few teachers with expertise in this area. To help attract chemists into teaching, at the time of writing the government pays a bursary of up to £5 000 to graduates who complete teacher education and one year of science teaching in a state-funded secondary school. There is discussion as to whether or not this initiative is successful in meeting its aims, as initial teacher education competes with higher status options for high quality graduate chemists and the proportion of pre-service science teachers who are chemists has remained at the same level now for around ten years.

Equality of access to triple award GCSE and post-16 chemistry courses is also discussed. The perceived lack of specialist chemistry teachers is associated with secondary schools being unable to offer single subject chemistry GCSE and A level courses, but other factors such as funding, facilities and pupil participation are also important. For example, data indicate that pupils in LAs with higher than average degrees of poverty tend to provide poorer access to single science subjects at GCSE [14]. However, the government claims further investments are being made to widen access – for example, science teachers are supported if they wish to develop chemistry expertise by attending additional training courses. Significantly, pupils from England performed very well in the most recent Trends in Mathematics and Science Survey [15], suggesting that by international comparison science knowledge levels of ten- and fourteen-year-olds are high. Although these pupils are younger than those taking GCSE, reliance on single subjects at GCSE as a "marker" for high quality standard science education is argued on this basis to be unfounded, and that achieving two science GCSEs at a high level is regarded as providing sufficient background knowledge for post-16 study.

Encouraging post-16 participation in chemistry has also been much discussed in the UK in recent years. Post-16 education has expanded in the last fifteen years, both in the numbers of pupils participating and in the range of courses made available. Sciences are regarded as "difficult" [16] and uncompromising in that they require learning of complex material with few opportunities to express personal opinion. Hence considerable efforts are made by science teachers to enhance post-16 participation using a wide range of initiatives such as science clubs, participation in "Chemistry Week" organized by the Royal Society of Chemistry and chemistry competitions. Chemistry-related careers are also strongly promoted.

University Chemistry in the UK

Single-subject chemistry degrees are available at forty-nine universities in the UK at the time of writing (source: Universities and Colleges Admissions Service, UCAS [17]). The standard qualification is a three-year "Bachelor of Science" (BSc) honours degree and, for those who wish to undertake advanced studies, an extra fourth year of research leading to a "Masters in Chemistry" (MChem) degree.

There are many variants – for example, nineteen universities offer a four-year MChem which includes a year studying abroad, while a large number permit chemistry to be studied with a range of other subjects including business, law, music and languages. Students can also spend their fourth year carrying out research in an industry placement. Studying one area of chemistry, such as polymer chemistry, analytical, industrial, medicinal, colour, food, environmental or materials, leading to a more specialized degree, is also a possibility. Universities offering such courses tend to have strong research traditions in these specialist areas. In total, about 12 500 undergraduate students were studying chemistry at UK universities in 2007/8 [18].

Across the UK, the university academic year begins in October and ends in June, usually divided into three ten-week units referred to as “terms”. All Chemistry degrees teach similar content, normally organized in modules covering physical, organic and inorganic aspects. At my present university, six modules are studied in each year. Typically, a chemistry module comprises twenty one hour lectures, twenty practical experiments each of three hours, and additional workshops and tutorials. Students are expected to read extensively in their own time. Most modules are examined by formal written examinations held in May each year. Some oral examinations are used to examine students’ knowledge of practical and data analysis skills, and some coursework is assessed. Students’ examination results are graded each year, leading to different levels of “Honours” being awarded for the complete degree – a “First Class” degree is the highest standard, awarded to students achieving 70% or higher in most of their assessments; followed by “Upper Second Class” (corresponding to scores of 60-69%), “Lower Second Class” (approximately 50–59%) and the lowest level of honours, “Third Class”. Students whose work does not meet Third Class standard may be awarded a Pass degree.

Concluding Comments

Overall, chemistry, along with science in general, is a highly respected subject in the UK, receiving extensive, mainly positive, attention from the media. Chemistry graduates are regarded as very employable, with most gaining jobs in chemistry or other related scientific fields. The chemical industry and the Royal Society of Chemistry [19] throughout the UK work hard with schools and universities to promote chemistry as a subject to help ensure the future supply of chemists they perceive is needed to maintain good industrial and professional research output.

At school, although chemistry tends to have reputation as a “difficult” subject, it remains a popular choice, particularly for academically oriented pupils. How best to widen access and encourage a broad range of pupils to study chemistry in school post-16 is frequently discussed – a new Science Diploma qualification [20] offers an “applied” science route focusing on how science is used in the workplace that is likely to attract new pupils to the subject.

Working as a chemistry teacher remains a satisfying and interesting profession. Although many changes have occurred to the science curriculum over the last twenty years, developing new ways of teaching and deciding how best to use the wide range of resources available for presenting chemistry topics to meet pupils’ learning needs is an ongoing challenge that requires ingenuity and creativity to solve. Encouraging pupils to pursue chemistry as a subject and to achieve high standards in public examinations is valued and respected by many.

References

[1] http://curriculum.qca.org.uk.

[2] http://www.nicurriculum.org.uk.

[3] http://schoolswork.co.uk/thinking/understanding-the-uk-education-system .

[4] Millar, R. and Osborne, J. (1998) Beyond 2000 Science Education for the Future London: School of Education, King’s College, London.

[5] Rose, J. (2009) Independent Review of the Primary Curriculum London: Department for Children, Schools and Families. http://publications.teachernet.gov.uk/eOrderingDownload/Primary_curriculum_Report.pdf.

[6] QCA (2007). http://curriculum.qcda.gov.uk/key-stages-3-and-4/subjects/science/index.aspx.

[7] Harrison, S. (2007) Specification GCSE Chemistry London: Pearson. http://www.edexcel.com/migrationdocuments/Current%20GCSE/UG018535_Science_2101new.pdf.

[8] EdExcel (2009). http://www.edexcel.com/migrationdocuments/Current%20GCSE/UG018535_Science_2101new.pdf.

[9] http://www.21stcenturyscience.org/the-courses.

[10] University of York Science Education Group (2006) Twenty First Century Science GCSE Chemistry Oxford: Oxford University Press.

[11] OCR (2009). http://www.ocr.org.uk/Data/publications/key_documents/GCSE_TFC_Chemistry_A_Specification.pdf.

[12] EdExcel (2008) Specification GCE Chemistry London: Pearson. http://www.edexcel.com/migrationdocuments/GCE%20New%20GCE/spec-gce-chemistry.pdf.

[13] Otter, C. (2008) Salters Advanced Chemistry Chemical Ideas 3rd Edition Oxford: Heinemann Educational Publishers.

[14] Curtis, P. (2009) State schools abandon single science GCSEs, The Guardian newspaper, 3rd June 2009. http://www.guardian.co.uk/education/2009/jun/03/science gcses-state-schools.

[15] Sturman, L., Ruddock, G., Burge, B., Styles, B., Lin, Y. and Vappula, H. (2008) England's achievement in TIMSS 2007 National report for England Slough: NFER. http://www.nfer.ac.uk/publications/pdfs/downloadable/timms/TIMSS2007Full-Report.pdf.

[16] Coe, R., Searle, J., Barmby, P., Jones, K. and Higgins, S. (2008) Relative difficulty of examinations in different subjects Summary Report. http://www.sciencecouncil.org/documents/SCORE2008summary.pdf.

[17] http://www.ucas.com.

[18] Higher Education Statistics Agency (2009) Students and qualifiers data tables. http://www.hesa.ac.uk/dox/dataTables/studentsAndQualifiers/download/subject-0708.xls?v=1.0.

[19] Royal Society of Chemistry (2006) Meeting industry's needs for chemistry graduates RSC Policy Bulletin, Issue 4.

[20] http://www.sciencediploma.co.uk.